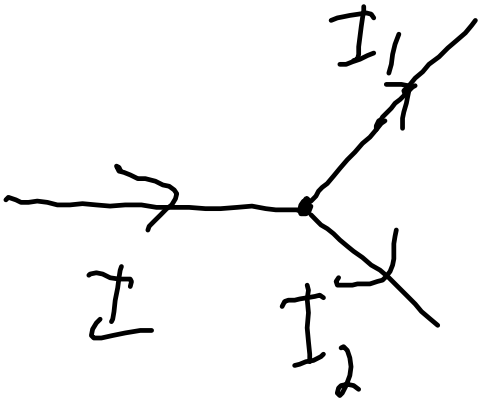
# Kirchhoff's Laws

## Laws for electric circuits

## From conservation of charge we can derive a junction law

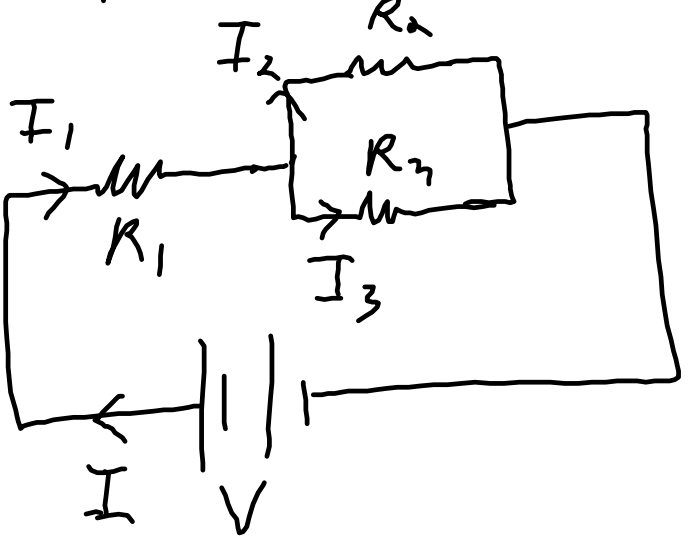



$I = I_1 + I_2$

KJL

Kirchhoff's Junction Law

## Loop Law




Conservation of energy

Power in = Power out

↑ battery

↖ resistors dissipating energy as heat

$$VI = I_1^2 R_1 + I_2^2 R_2 + I_3^2 R_3$$

or

$$V\boxed{I} = V_1\boxed{I_1} + V_2 I_2 + V_3 I_3$$

$$VI = V_1 I + V_2 I_2 + V_3 I_3$$

$$I = I_2 + I_3 .$$

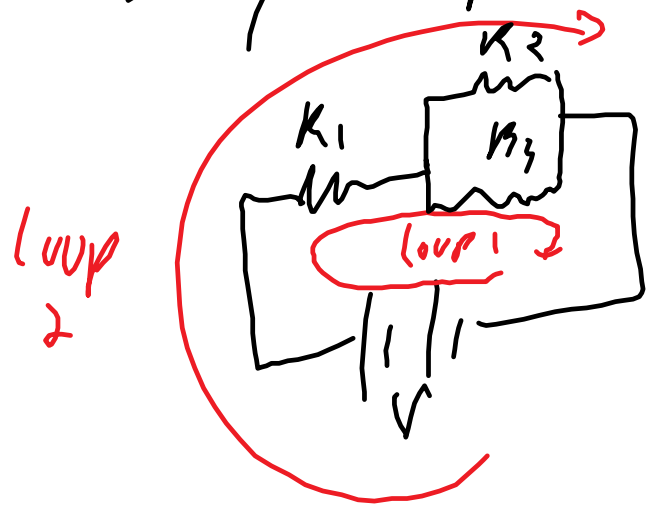
So if $V_2 = V_3$

$$VI = V_1 I + (V_{23})\, I$$

$$\boxed{V = V_1 + V_{23}}$$

loop Law voltages around

"any loop add to zero.




loop 1

$V = V_1 + V_3$

loop 2

$V = V_1 + V_2$

eg. in the above circuit, set

$V = 6.0\,V$ $R_1 = 100\,\Omega$

$R_2 = 250\,\Omega$ $R_3 = 500\,\Omega$

Determine a) $R_T$

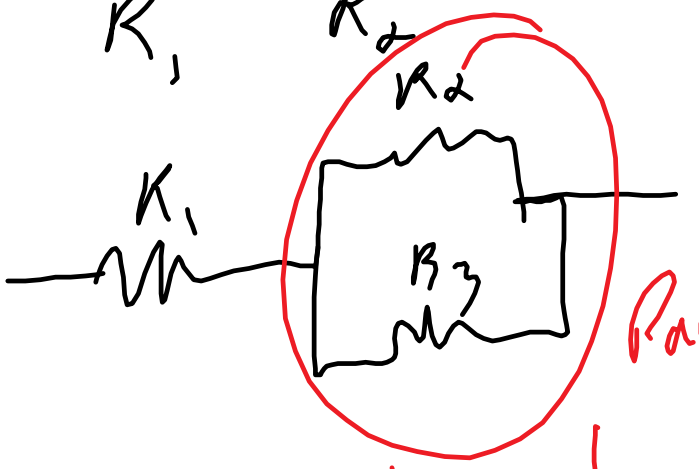
b) $I_1, I_2, I_3$

c) $V_1, V_2, V_3$

d) which resistor dissipates most power? what is the power output?

$R_T = R_1 + R_2 \cdots$ Series

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \quad \text{Parallel}$$




Parallel

$$\frac{1}{R_{T_2}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{250} + \frac{1}{500}$$

$$\frac{1}{R_{T_2}} = \frac{3}{500} \qquad R_{T_2} = \frac{500}{3}$$

$$R_{T_2} = 167\,\Omega$$

$$R_T = R_1 + R_{T_2} = \boxed{267\,\Omega}$$

b) $$I = \frac{V}{R_T} = \frac{6\,V}{267\,\Omega} = 23\,mA$$

$$I_1 = I$$

$$I_2 = ? \qquad \frac{V_2}{R_2} = \frac{V - V_1}{R_2} \quad \rightarrow 2.3\,V$$

$$\frac{10\,V - 0.023\,A\,(100\,\Omega)}{} = \frac{3.7\,V}{}$$

$$= \frac{6.0V - 0.023A(100\Omega)}{250\Omega} = \frac{5.7V}{250\Omega}$$

$$I_2 = \boxed{0.0148\,A}$$

$$I_3 = \frac{3.7V}{500\Omega} = \boxed{0.0074A}$$

$V = 6V \quad V_1 = 2.3V \quad V_2 = V_3 = 3.7V$

$$P_1 = I^2 R_1 = 0.023^2 * 100$$

$$* \boxed{P_2} = I^2 R_2 = 0.014^2 (250)$$

Block 1-2

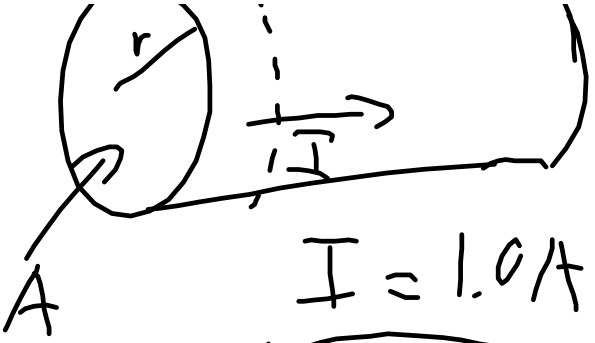
Electric Circuits and Kirchhoff's Laws

Q9 p 477

$r = 1mm$

$\rho = 10^{29} e^-/m^3$


$I = ?$




$v = ?$

$I = 1.0\,A$

$$I = \frac{\Delta q}{\Delta t} \qquad \rho = \frac{q}{V}$$

$$I = \frac{\rho V}{\Delta t} \qquad V = \pi r^2 \Delta L$$

$$I = \rho \pi r^2 \frac{\Delta L}{\Delta t}$$

$\frac{\Delta L}{\Delta t} = v$

$$I = \rho \pi r^2 v$$

$$v = \frac{1.0\,A \left(\frac{C}{s}\right)}{10^{29}\,\frac{e^-}{m^3}\,(3.14)\left(1.0\times10^{-3}\,m\right)^2\,1.60\times10^{-19}\,\frac{C}{e^-}}$$

$$\boxed{v = 2.0\times10^{-5}\ m/s}$$

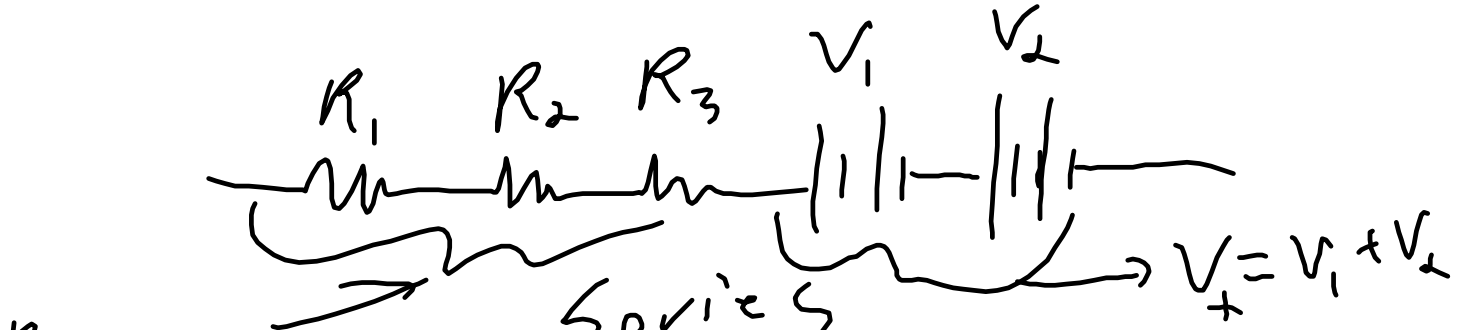
Q 31 $P_{in} = P_{out}$

$$VI = \frac{mc\Delta T}{t}$$

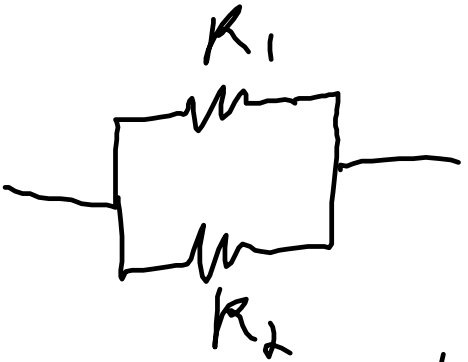
$$\frac{m}{t} = \frac{VI}{c\Delta T}$$

Electric Circuits

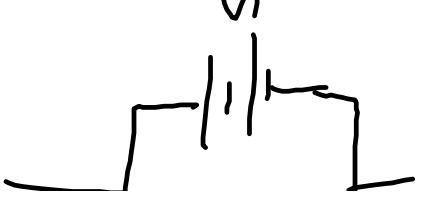
Series circuit: circuits elements are one after the other.




Parallel



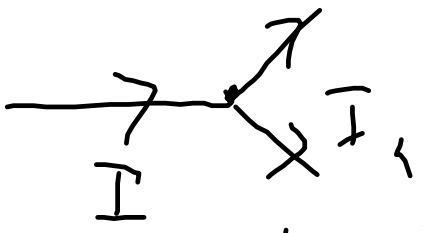

equivalent resistance → $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$




$V_T = V_1 = V_2$


Law of conservation of charge - charge is not created or destroyed.

Kirchhoff's Junction Law: $I_1$




$$I = I_1 + I_2$$

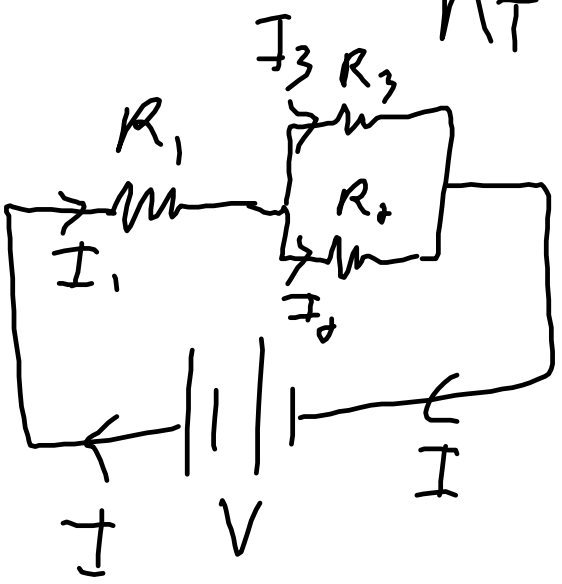
$V = IR$


$$I = I_1 + I_2$$

$$\frac{V}{R_T} = \frac{V_1}{R_1} + \frac{V_2}{R_2}$$

$$V = V_1 = V_2$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$




← mixed circuit

$I = I_1$

Law of Conservation of energy

$P_{input} = P_{output}$

↑ battery

↑ resistors → emit heat

$VI = V_1 I_1 + V_2 I_2 + V_3 I_3$

$V_2 = V_3$

$I = I_2 + I_3$

$V_2 (I_2 + I_3)$

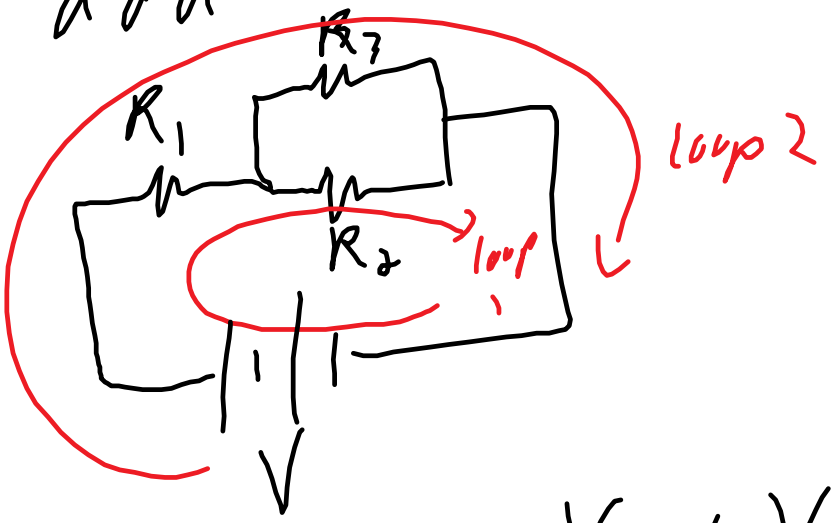
$VI = V_1 I + V_2 I$

$V = V_1 + V_2$ or

$V = V_1 + V_3$

Kirchhoff's Loop Law

- Voltages around a loop add to zero.




loop 1 $V = V_1 + V_2$

loop 2 $V = V_1 + V_3$

e.g. In the above diagram

Set $V = 6.0\,V$, $R_1 = 100\,\Omega$

$R_2 = 250\,\Omega$ $R_3 = 500\,\Omega$

Determine

a) equivalent resistance
- Parallel resistors
- whole circuit

b) $V_1, V_2, V_3$

c) $I, I_1, I_2, I_3$

$$\frac{1}{R_{T_2}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{250} + \frac{1}{500}$$

$$\frac{1}{R_{T_2}} = \frac{3}{500} \quad R_{T_2} = 167\Omega$$

$$R_T = R_1 + R_{T_2} = 100 + 167$$

Series

$$\boxed{R_T = 267\Omega}$$

$$I = \frac{V}{R_T} = \frac{6.0V}{267\Omega} = 0.0225\ A$$

$$V_1 = IR_1 = 0.0225A \times 100\Omega$$

$$\boxed{V_1 = 2.25\ V}$$

Loop law $V = V_1 + V_2$

$$V_2 = V_3 = 6 - 2.25$$

$$\boxed{V_2 = V_3 = 3.75\ V}$$

$$I_1 = I$$

$$I_2 = \frac{V_2}{R_2} = \frac{3.75}{250} = 0.015A$$

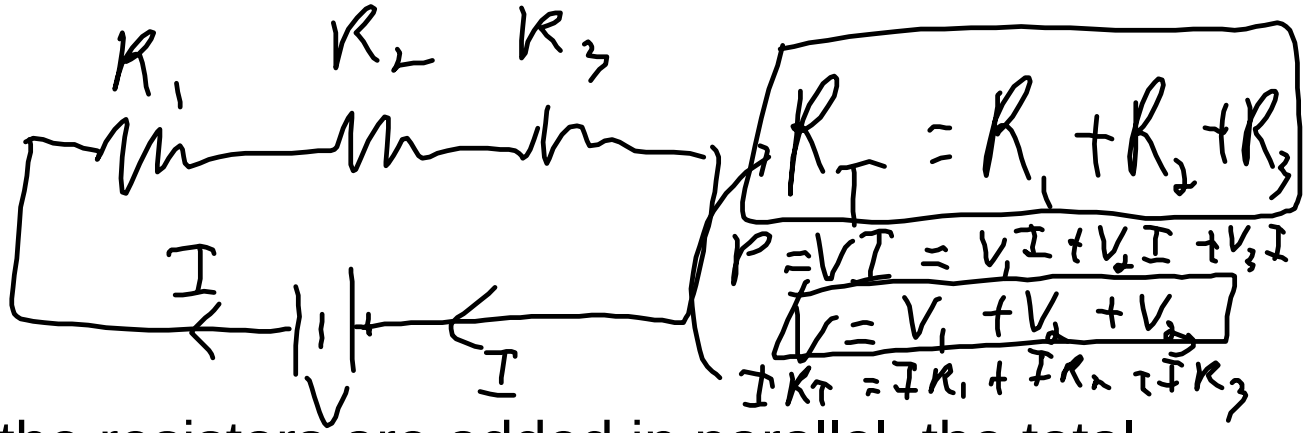
$$\underline{I_3 = 0.0075A}$$

Which resistor gives off the most heat?

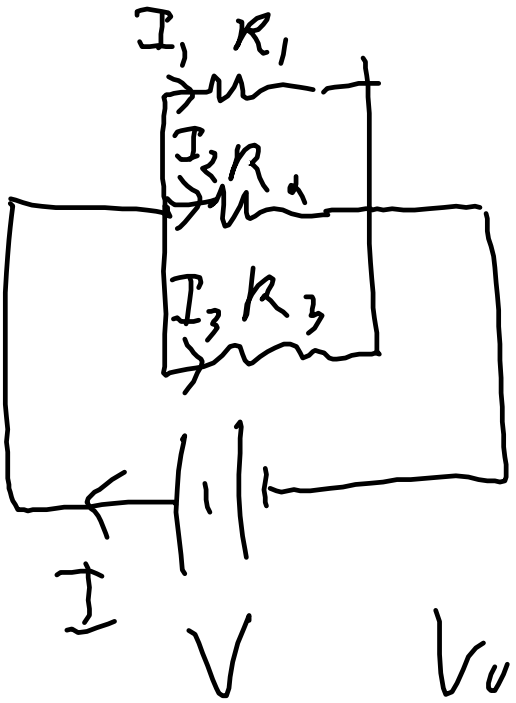
Electric Circuits and Kirchhoff's Laws

Resistor - dissipates electrical energy as heat, thus reducing the current for a particular voltage.

If you add multiple resisters in series, the resistance of the circuit increases.




If the resistors are added in parallel, the total resistance decreases.




Junction Law

$$I = I_1 + I_2 + I_3$$

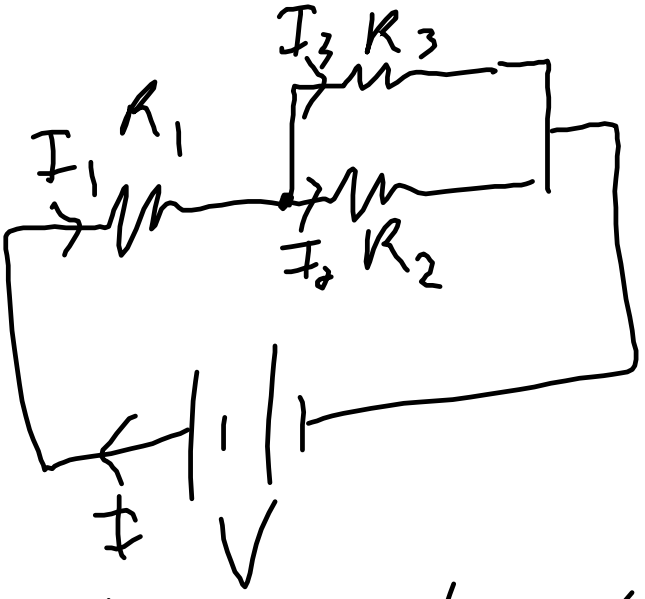
$$\frac{V}{R_T} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

Voltages in parallel are equal

$$V = V_1 = V_2 = V_3$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Mixed Circuit




Kirchhoff's Loop Law

$$I = I_1 = I_2 + I_3$$

$$P_{in} = P_{out}$$

$$VI = V_1 I + V_2 I_2 + V_3 I_3$$

$$V - V_1 = I$$

$V_2 = V_3$

$= I$

$VI = V_1 I + V_2 (I_2 + I_3)$

$VI = V_1 I + V_2 I$

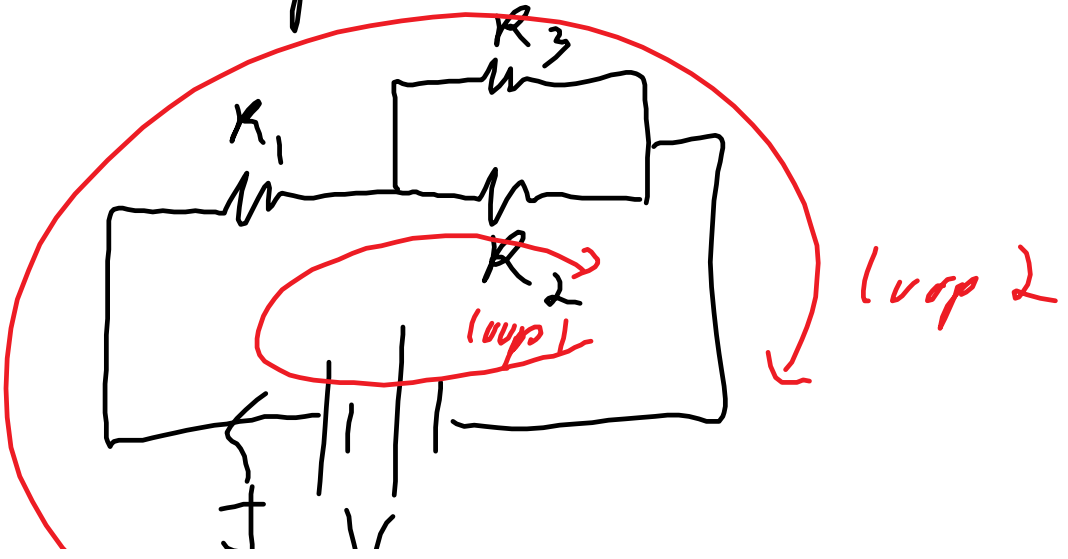
$V = V_1 + V_2$

or

$V = V_1 + V_3$

Kirchhoff's Loop Law

- Voltages around a loop add to zero.



$\pm V$

loop 1 $V = V_1 + V_2$ *

loop 2 $V = V_1 + V_3$

eg.

In the above circuit, the battery voltage is 6.0V, $R_1$=100 ohms, $R_2$= 250 ohms and $R_3$ = 500 ohms.

Determine

a) Equivalent resistance, $R_T$ of the parallel section.
b) Equivalent resistance, $R_T$ of the whole circuit.
c) Current out of the battery, I
d) Voltage across $R_1$
e) V and I of $R_2$ and $R_3$
f) Which resistor gives off the most heat?

P498 Q1,2,3

P499 problems 1-11 odds